∗ R3134K (DFN(PLP)1212-6) and R3134Q (SC-88A) are the discontinued products as of March, 2016.

RICOH

R3134x SERIES

LOW VOLTAGE DETECTOR WITH BUILT-IN DELAY CIRCUIT

NO.EA-209-160316

OUTLINE

R3134x Series are CMOS-based voltage detector ICs with built-in delay circuit, high detector threshold accuracy, and ultra low supply current, which can operate at low voltage.

These ICs can be used as system reset generators, and each of these ICs consists of a voltage reference, a comparator, resistors for setting voltage detector threshold, an output driver transistor, manual reset circuit, and an output delay generator.

Detector threshold is fixed internally with high accuracy and requires no adjustment. When a supply voltage crosses a setting detector threshold voltage from a high value to a lower value, this IC generates reset signal.

R3134x Series output "L" at its detect.

Since each of R3134x Series embeds an output delay generator, during a setting 240ms delay time, which is fixed in the IC, this IC keeps the reset condition after they are released. Released conditions will be kept for the delay time from when a supply voltage crosses a setting detector threshold voltage from a low value to a higher value, or from when the manual reset signal is released.

Two output types, Nch open drain type and CMOS type, are available.

Since the packages for these ICs are DFN(PLP)1212-6, SOT-23-5, and SC-88A, high density mounting of the ICs on board is possible.

FEATURES

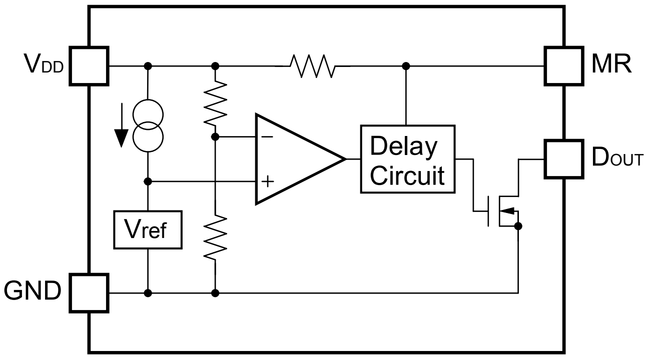
• Supply Current	Typ. 0.8µA (R3134x27Ex, V_{DD}=3.0V)
• Operating Voltage Range	0.75V to 6.0V (T_{opt}=25°C)
• Detector Threshold Range	1.0V to 5.0V (0.1V steps) Further, 2.32V, 2.63V, 2.93V, 3.08V, 4.38V, and 4.63V can be provided as standard.
• Detector Threshold Accuracy	±1.8%
• Temperature-Drift Coefficient of Detector Threshold	Typ. ±100ppm/°C
• Built-in Delay Time Circuit	Typ. 240ms
• Output Delay Time Accuracy	±15%
• Output Types	Nch Open Drain and CMOS
• Packages	DFN(PLP)1212-6, SC-88A, SOT-23-5

APPLICATIONS

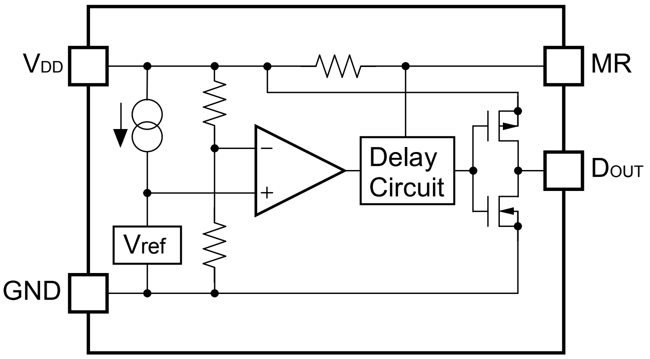
- CPU and Logic Circuit Reset
- Battery Checker
- Window Comparator
- Wave Shaping Circuit
- Battery Back-up Circuit
- Power Failure Detector

BLOCK DIAGRAMS

Nch Open Drain Output (R3134xxxEA)



CMOS Output (R3134xxxEC)



SELECTION GUIDE

The package type, the detector threshold, the output type and the taping type for the ICs can be selected at the users' request.

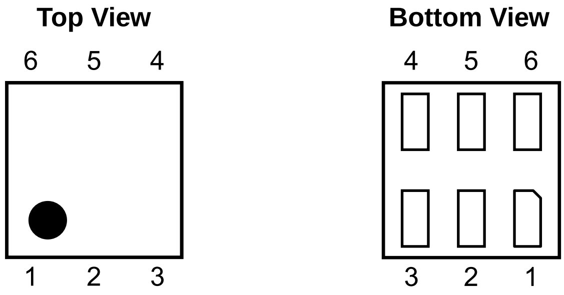
Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R3134KxxE∗(y)-TR	DFN(PLP)1212-6	5,000 pcs	Yes	Yes
R3134QxxE∗(y)-TR-FE	SC-88A	3,000 pcs	Yes	Yes
R3134NxxE∗(y)-TR-FE	SOT-23-5	3,000 pcs	Yes	Yes

xx: The detector threshold can be designated in the range from 1.0V(10) to 5.0V(50) in 0.1V steps.
y: If the detector threshold includes the 3rd digit, indicate the digit of 0.01V.
(Example) If the detector threshold is 2.63V, R3134x26E∗3-TR-x

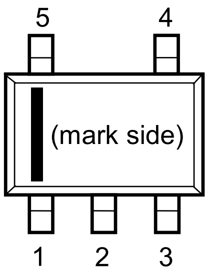
∗ : Designation of Output Type
(A) Nch Open Drain
(C) CMOS

PIN CONFIGURATIONS

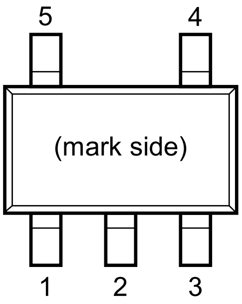
- **DFN(PLP)1212-6**



- **SC-88A**



- **SOT-23-5**



PIN DESCRIPTIONS

- **DFN(PLP)1212-6**

Pin No.	Symbol	Description
1	V_{DD}	Input Pin
2	NC	No Connection
3	GND	Ground Pin
4	D_{OUT}	Output Pin ("L" at detection)
5	NC	No Connection
6	MR	Manual Reset Input Pin*

- **SC-88A**

Pin No.	Symbol	Description
1	V_{DD}	Input Pin
2	GND	Ground Pin
3	MR	Manual Reset Input Pin*
4	D_{OUT}	Output Pin ("L" at detection)
5	NC	No Connection

- **SOT-23-5**

Pin No.	Symbol	Description
1	D_{OUT}	Output Pin ("L" at detection)
2	V_{DD}	Input Pin
3	GND	Ground Pin
4	MR	Manual Reset Input Pin*
5	NC	No Connection

*) MR pin is active at "L" input. Pulled up via 1MΩ (Typ.). If MR pin is not necessary, open this node, or connect it to V_{DD}.

ABSOLUTE MAXIMUM RATINGS

Symbol	Item	Rating	Unit
V_{DD}	Supply Voltage	6.5	V
V_{OUT}	Output Voltage (Nch Open Drain Output)	V_{SS}–0.3 to 6.5	V
	Output Voltage (CMOS Output)	V_{SS}–0.3 to V_{DD}+0.3	
V_{MR}	Input Voltage	V_{SS}–0.3 to V_{DD}+0.3	V
I_{OUT}	Output Current	20	mA
P_D	Power Dissipation (DFN(PLP)1212-6)*	400	mW
	Power Dissipation (SC-88A)*	380	
	Power Dissipation (SOT-23-5)*	420	
T_{opt}	Operating Temperature Range	–40 to 85	°C
T_{stg}	Storage Temperature Range	–55 to 125	°C

∗) For Power Dissipation, please refer to PACKAGE INFORMATION.

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

ELECTRICAL CHARACTERISTICS

- **R3134x**

The specification in ☐ is checked and guaranteed by design engineering at –40°C ≤ Topt ≤ 85°C.

Topt=25°C

Symbol	Item	Conditions		Min.	Typ.	Max.	Unit
V_{DET}	Detector Threshold			V_{DET} ×0.982		V_{DET} ×1.018	V
I_{SS1}	Supply Current1	$V_{DD}=V_{DET}-0.1V$, $I_{OUT}=0A$				2.0	μA
I_{SS2}	Supply Current2	$V_{DD}=V_{DET}+0.1V$, $I_{OUT}=0A$				2.0	μA
I_{SS3}	Supply Current3	$V_{DD}=6V$, $I_{OUT}=0A$	$V_{DET} < 1.6V$			3.6	μA
			$1.6 \leq V_{DET} < 2.7V$			3.0	
			$2.7V \leq V_{DET}$			2.5	
V_{DD}	Operating Voltage	Topt=25°C		0.75		6.00	V
		–40°C ≤ Topt ≤ 85°C		$\boxed{0.85}$		$\boxed{6.00}$	
V_{OH}	"H" Output Voltage	Refer to the following table					
V_{OL}	"L" Output Voltage	Refer to the following table					
V_{IH}	MR pin "H" Input Voltage	$V_{DD} \geq V_{DET}+0.1V$		$0.75 \times V_{DD}$			V
V_{IL}	MR pin "L" Input Voltage	$V_{DD} \geq V_{DET}+0.1V$				$0.2 \times V_{DD}$	V
R_{MR}	MR pin pull-up Resistance	Topt=25°C		0.5	1.0	4.0	MΩ
$\Delta V_{DET}/\Delta Topt$	Detector Threshold Temperature Coefficient	–40°C ≤ Topt ≤ 85°C			±100		ppm /°C
t_{reset}	Output Delay Time for detect *	$V_{DD}=V_{DET} \rightarrow V_{DET}-0.1V$			15		μs
t_{delay}	Output Delay Time for release	$V_{DD}=0.8V \rightarrow V_{DET}+1.0$		204	240	276	ms

∗) Guaranteed by design, not mass production tested.

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

"H" Output Voltage (V_{OH}) table

Topt=25°C

Products	Detector Threshold V_{DET} (V)	"H" Output Voltage V_{OH} (V)			
		Conditions	Min.	Typ.	Max.
R3134xxxEC	V_{DET} < 1.2V	V_{DD}=V_{DET}+0.1V, I_{OH}=50μA	0.8×V_{DD}		
	1.2V ≤ V_{DET} < 2.0V	V_{DD}=V_{DET}+0.1V, I_{OH}=150μA			
	2.0V ≤ V_{DET} < 3.1V	V_{DD}=V_{DET}+0.1V, I_{OH}=500μA			
	3.1V ≤ V_{DET}	V_{DD}=V_{DET}+0.1V, I_{OH}=800μA			

V_{DET} is a set value.

"L" Output Voltage (V_{OL}) table

Topt=25°C

Products	Detector Threshold V_{DET} (V)	"L" Output Voltage V_{OL} (V)			
		Conditions	Min.	Typ.	Max.
R3134xxxEx	V_{DET} < 1.2V	V_{DD}=V_{DET}−0.1V, I_{OL}=200μA			0.04
	1.2V ≤ V_{DET} < 2.0V	V_{DD}=V_{DET}−0.1V, I_{OL}=750μA			0.06
	2.0V ≤ V_{DET} < 3.1V	V_{DD}=V_{DET}−0.1V, I_{OL}=1.2mA			0.05
	3.1V ≤ V_{DET}	V_{DD}=V_{DET}−0.1V, I_{OL}=3.2mA			0.06

V_{DET} is a set value.

∗ R3134K (DFN(PLP)1212-6) and R3134Q (SC-88A) are the discontinued products as of March, 2016.

DETECTOR THRESHOLD SPECIFICATIONS BY PART NUMBER

- **R3134x**

Part Number	Operating Voltage				Detector Threshold			Supply Current 1		
	V_{DD} [V]				V_{DET} [V]			I_{SS1} [μA]		
	Conditions	Min.	Conditions	Min.	Min.	Typ.	Max.	Conditions	Typ.	Max.
R3134x23Ex2	Topt=25°C	0.75	−40°C ≤ Topt ≤ 85°C	0.85	2.278	2.320	2.362	V_{DD}=V_{DET}−0.1V I_{OUT}=0A	0.8	2.0
R3134x26Ex3					2.583	2.630	2.677			
R3134x29Ex3					2.877	2.930	2.983		0.9	
R3134x30Ex8					3.025	3.080	3.135			
R3134x43Ex8					4.301	4.380	4.459			
R3134x46Ex3					4.547	4.630	4.713			
R3134x10Ex	Topt=25°C	0.75	−40°C ≤ Topt ≤ 85°C	0.85	0.982	1.000	1.018	V_{DD}=V_{DET}−0.1V I_{OUT}=0A	0.8	2.0
R3134x11Ex					1.080	1.100	1.120			
R3134x12Ex					1.178	1.200	1.222			
R3134x13Ex					1.277	1.300	1.323			
R3134x14Ex					1.375	1.400	1.425			
R3134x15Ex					1.473	1.500	1.527			
R3134x16Ex					1.571	1.600	1.629			
R3134x17Ex					1.669	1.700	1.731			
R3134x18Ex					1.768	1.800	1.832			
R3134x19Ex					1.866	1.900	1.934			
R3134x20Ex					1.964	2.000	2.036			
R3134x21Ex					2.062	2.100	2.138			
R3134x22Ex					2.160	2.200	2.240			
R3134x23Ex					2.259	2.300	2.341			
R3134x24Ex					2.357	2.400	2.443			
R3134x25Ex					2.455	2.500	2.545			
R3134x26Ex					2.553	2.600	2.647			
R3134x27Ex					2.651	2.700	2.749		0.9	
R3134x28Ex					2.750	2.800	2.850			
R3134x29Ex					2.848	2.900	2.952			
R3134x30Ex					2.946	3.000	3.054			
R3134x31Ex					3.044	3.100	3.156			
R3134x32Ex					3.142	3.200	3.258			
R3134x33Ex					3.241	3.300	3.359			
R3134x34Ex					3.339	3.400	3.461			
R3134x35Ex					3.437	3.500	3.563			
R3134x36Ex					3.535	3.600	3.665			
R3134x37Ex					3.633	3.700	3.767			
R3134x38Ex					3.732	3.800	3.868			
R3134x39Ex					3.830	3.900	3.970			
R3134x40Ex					3.928	4.000	4.072			
R3134x41Ex					4.026	4.100	4.174			
R3134x42Ex					4.124	4.200	4.276			
R3134x43Ex					4.223	4.300	4.377			
R3134x44Ex					4.321	4.400	4.479			
R3134x45Ex					4.419	4.500	4.581			
R3134x46Ex					4.517	4.600	4.683			
R3134x47Ex					4.615	4.700	4.785			
R3134x48Ex					4.714	4.800	4.886			
R3134x49Ex					4.812	4.900	4.988			
R3134x50Ex					4.910	5.000	5.090			

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Supply Current 2			**Supply Current 3**			**"H" Output Voltage**	
I_{SS2} [µA]			**I_{SS3} [µA]**			**V_{OH} [V]**	
Conditions	**Typ.**	**Max.**	**Conditions**	**Typ.**	**Max.**	**Conditions**	**Min.**
V_{DD}=V_{DET}+0.1V I_{OUT}=0A	0.8	2.0	V_{DD}=6.0V I_{OUT}=0A	1.2	3.0	V_{DD}=V_{DET}+0.1V I_{OH}=500µA	0.8× V_{DD}
				1.0	2.5		
						V_{DD}=V_{DET}+0.1V I_{OH}=800µA	
V_{DD}=V_{DET}+0.1V I_{OUT}=0A	0.8	2.0	V_{DD}=6.0V I_{OUT}=0A	1.4	3.6	V_{DD}=V_{DET}+0.1V I_{OH}=50µA	0.8× V_{DD}
						V_{DD}=V_{DET}+0.1V I_{OH}=150µA	
					3.0		
						V_{DD}=V_{DET}+0.1V I_{OH}=500µA	
				1.2			
				1.0	2.5		
						V_{DD}=V_{DET}+0.1V I_{OH}=800µA	
				0.8			

∗ R3134K (DFN(PLP)1212-6) and R3134Q (SC-88A) are the discontinued products as of March, 2016.

Part Number	"L" Output Voltage		MR pin "H" Input Voltage		MR pin "L" Input Voltage		MR pin pull-up resistance			
	V_{OL} [V]		V_{IH} [V]		V_{IL} [V]		R_{MR} [MΩ]			
	Conditions	**Max.**	**Conditions**	**Min.**	**Conditions**	**Max.**	**Conditions**	**Min.**	**Typ.**	**Max.**
R3134x23Ex2	$V_{DD}=V_{DET}-0.1V$ $I_{OL}=1.2mA$	0.05	$V_{DD} \geq V_{DET}+0.1$	$0.75\times V_{DD}$	$V_{DD} \geq V_{DET}+0.1$	$0.2\times V_{DD}$	Topt=25°C	0.5	1.0	4.0
R3134x26Ex3										
R3134x29Ex3										
R3134x30Ex8										
R3134x43Ex8	$V_{DD}=V_{DET}-0.1V$ $I_{OL}=3.2mA$	0.06								
R3134x46Ex3										
R3134x10Ex	$V_{DD}=V_{DET}-0.1V$ $I_{OL}=200\mu A$	0.04	$V_{DD} \geq V_{DET}+0.1$	$0.75\times V_{DD}$	$V_{DD} \geq V_{DET}+0.1$	$0.2\times V_{DD}$	Topt=25°C	0.5	1.0	4.0
R3134x11Ex										
R3134x12Ex	$V_{DD}=V_{DET}-0.1V$ $I_{OL}=750\mu A$	0.06								
R3134x13Ex										
R3134x14Ex										
R3134x15Ex										
R3134x16Ex										
R3134x17Ex										
R3134x18Ex										
R3134x19Ex										
R3134x20Ex	$V_{DD}=V_{DET}-0.1V$ $I_{OL}=1.2mA$	0.05								
R3134x21Ex										
R3134x22Ex										
R3134x23Ex										
R3134x24Ex										
R3134x25Ex										
R3134x26Ex										
R3134x27Ex										
R3134x28Ex										
R3134x29Ex										
R3134x30Ex										
R3134x31Ex	$V_{DD}=V_{DET}-0.1V$ $I_{OL}=3.2mA$	0.06								
R3134x32Ex										
R3134x33Ex										
R3134x34Ex										
R3134x35Ex										
R3134x36Ex										
R3134x37Ex										
R3134x38Ex										
R3134x39Ex										
R3134x40Ex										
R3134x41Ex										
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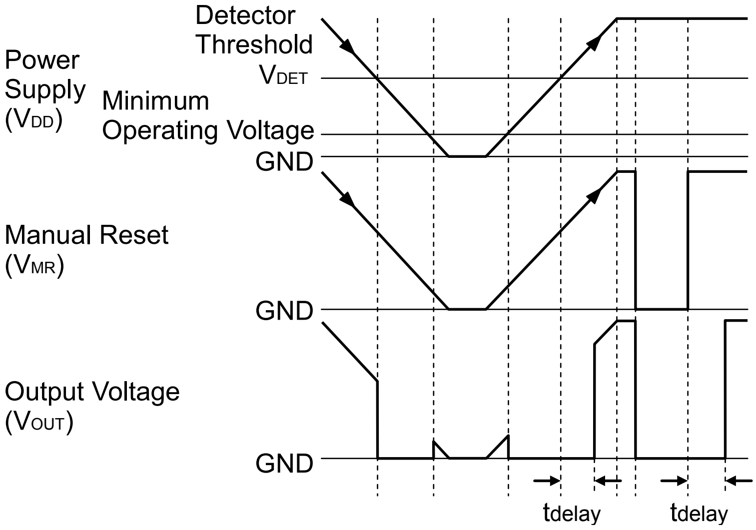
R3134x43Ex										
R3134x44Ex										
R3134x45Ex										
R3134x46Ex										
R3134x47Ex										
R3134x48Ex										
R3134x49Ex										
R3134x50Ex										

Output Delay Time for Release				Detector Threshold Temperature Coefficient	
tdelay [ms]				$\Delta V_{DET}/\Delta Topt$ [ppm/°C]	
Conditions	**Min.**	**Typ.**	**Max.**	**Conditions**	**Typ.**
V_{DD}=0.8V→ V_{DET}+1.0V Topt=25°C	204	240	276	$-40°C \le Topt \le 85°C$	±100
V_{DD}=0.8V→ V_{DET}+1.0V Topt=25°C	204	240	276	$-40°C \le Topt \le 85°C$	±100

TIMING CHART



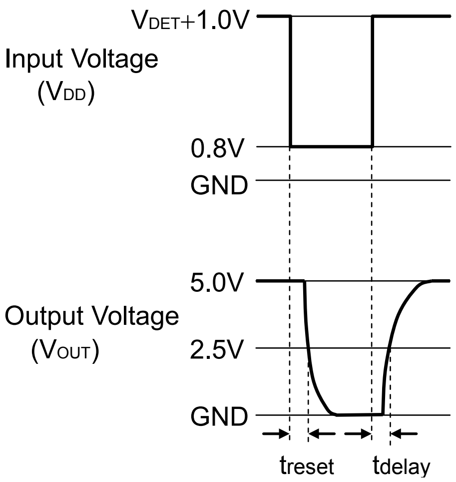
R3134x Operating Diagram

DEFINITION OF OUTPUT DELAY TIME

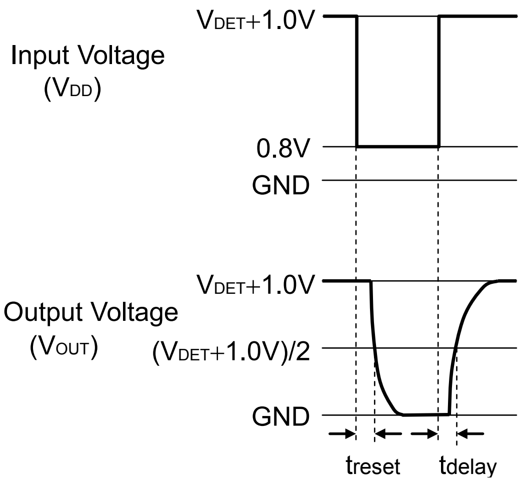
Output Delay Time (tdelay) is specified as follows:

1. In the case of Nch Open Drain Output:
   The time interval from rising edge of V_{DD} pulse 0.8V to V_{DET}+1.0V to the time at which the output reaches 2.5V under the condition that the output pin (D_{OUT}) is pulled up to 5V through a 470kΩ resistor.

2. In the case of CMOS Output:
   The time interval from rising edge of V_{DD} pulse 0.8V to V_{DET}+1.0V to the time at the output reaches (V_{DET}+1.0V)/2.



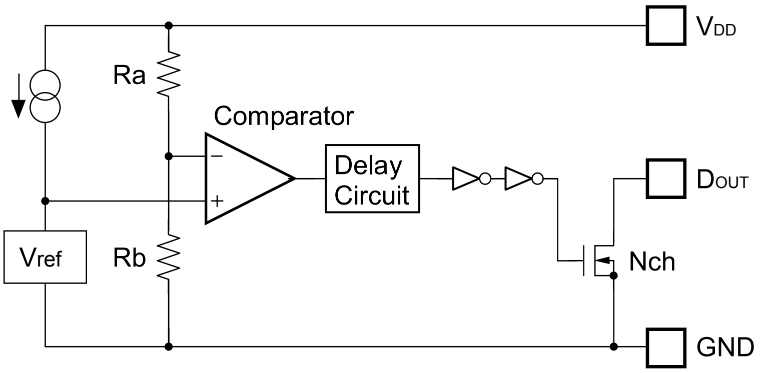
Nch Open Drain Output (R3134xxxEA)



CMOS Output (R3134xxxEC)

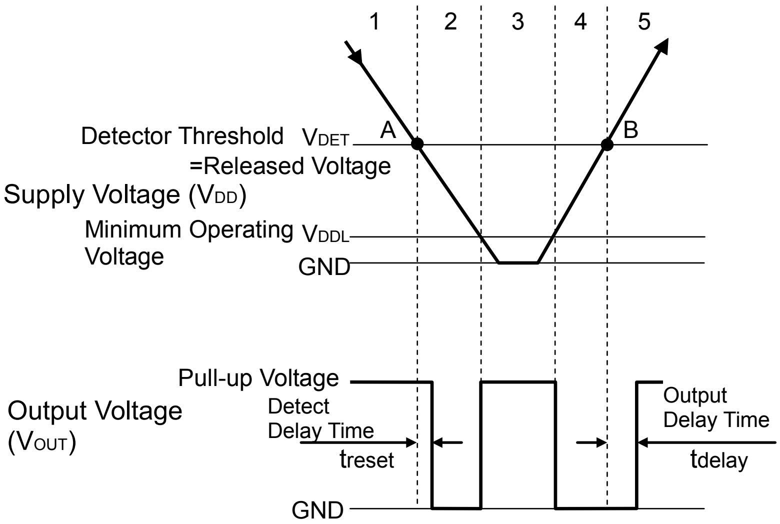
OPERATION

● Operation of R3134xxxEA



D_{OUT} pin should be pulled-up to an external voltage level.

Block Diagram



Operation Diagram

● Explanation of operation

Step 1. The output voltage is equal to the pull-up voltage.

Step 2. At Point "A", $V_{ref} \geq V_{DD} \times Rb/(Ra+Rb)$ is true, as a result, the output of comparator is reversed from "L" to "H", therefore the output voltage becomes the GND level. The voltage level of Point A means a detector threshold voltage (V_{DET}).

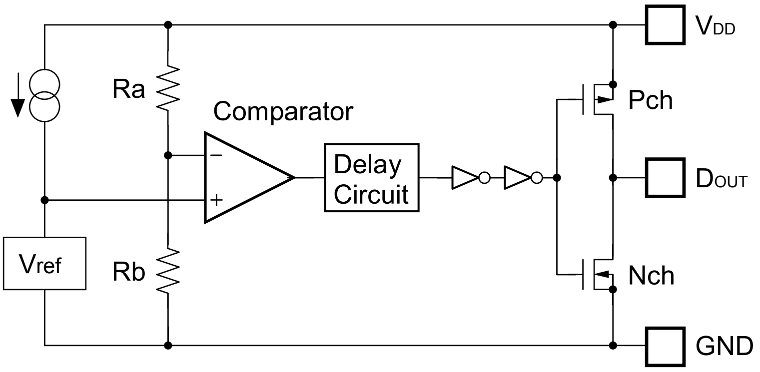
Step 3. When the supply voltage is lower than the minimum operating voltage, the operation of the output transistor becomes indefinite. The output voltage is equal to the pull-up voltage.

Step 4. The output voltage is equal to the GND level.

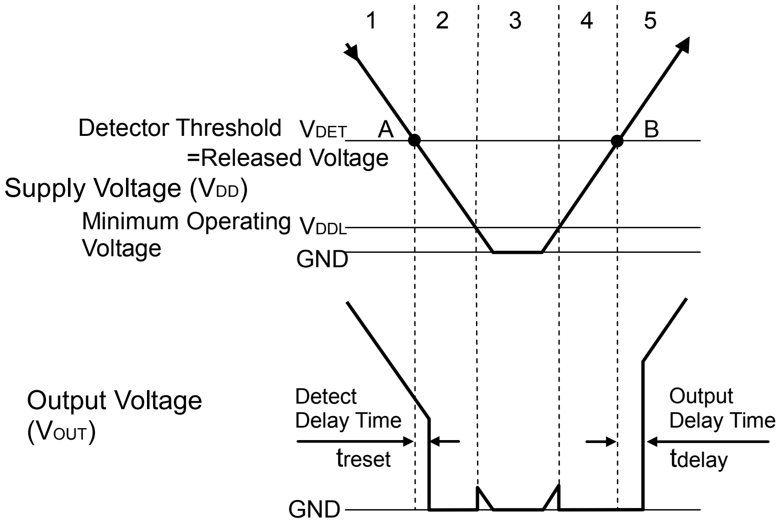
Step 5. At Point "B", $V_{ref} \leq V_{DD} \times Rb/(Ra+Rb)$ is true, as a result, the output of comparator is reversed from "H" to "L", then the output voltage is equal to the pull-up voltage. The voltage level of Point B means a released voltage (V_{DET}).

∗) There is no hysteresis range between the detector threshold and the released voltage.

● Operation of R3134xxxEC



Block Diagram



Operation Diagram

● Explanation of operation

Step 1. The output voltage is equal to the supply voltage (V_{DD}).

Step 2. At Point "A", $V_{ref} \geq V_{DD} \times Rb/(Ra+Rb)$ is true, as a result, the output of comparator is reversed from "L" to "H", therefore the output voltage becomes the GND level. The voltage level of Point A means a detector threshold voltage (V_{DET}).

Step 3. When the supply voltage is lower than the minimum operating voltage, the operation of the output transistor becomes indefinite.

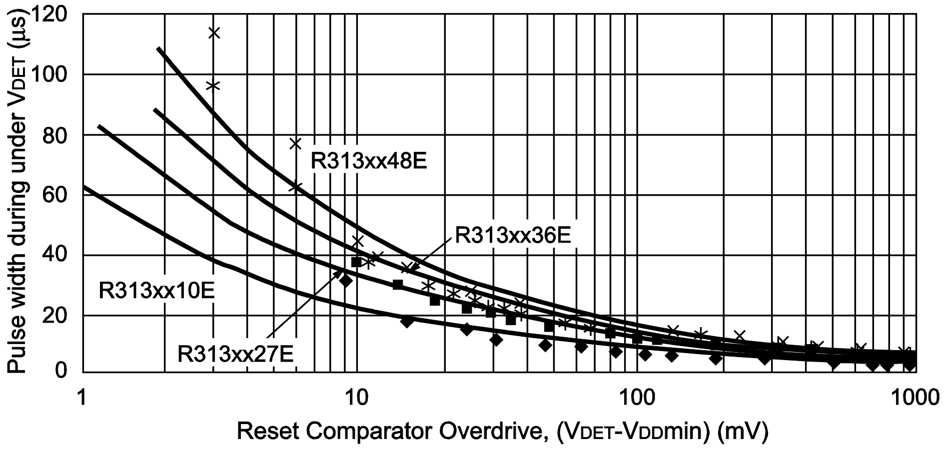
Step 4. The output voltage is equal to the GND level.

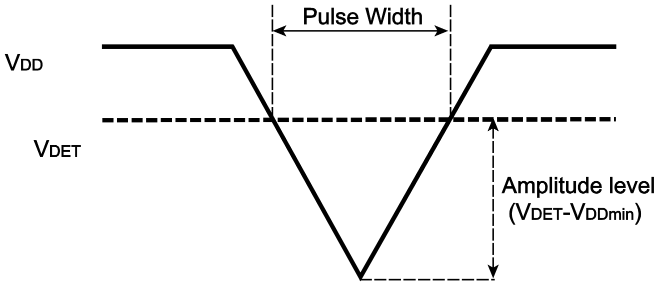
Step 5. At Point "B", $V_{ref} \leq V_{DD} \times Rb/(Ra+Rb)$ is true, as a result, the output of comparator is reversed from "H" to "L", then the output voltage is equal to the supply voltage (V_{DD}). The voltage level of Point B means a released voltage (V_{DET}).

∗) There is no hysteresis range between the detector threshold and the released voltage.

Detector Operation vs. glitch input voltage to the V_{DD} pin

When the IC is released and a large pulse (glitch) crosses the detector threshold is forced, the IC may not maintain the released condition. The amplitude of the pulse (V_{DET}-V_{DD}min) and the pulse width the IC can maintain the released level is described in the graph as follows:

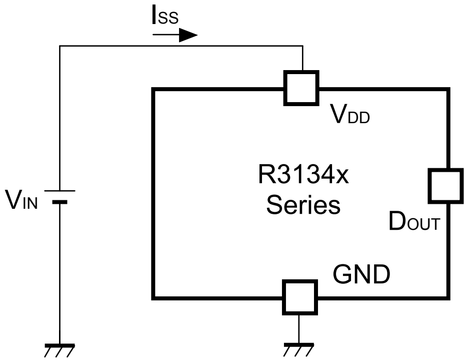




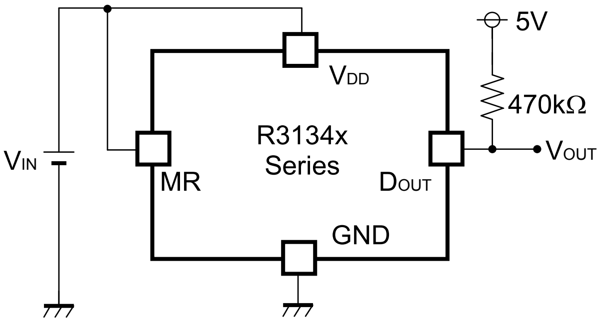
V_{IN} Input Waveform

The graph above shows the condition for the maximum transient duration without generating a reset. If the larger amplitude or larger pulse width noise than the graph may be on the V_{DD}, the reset signal may be generated.

TEST CIRCUITS

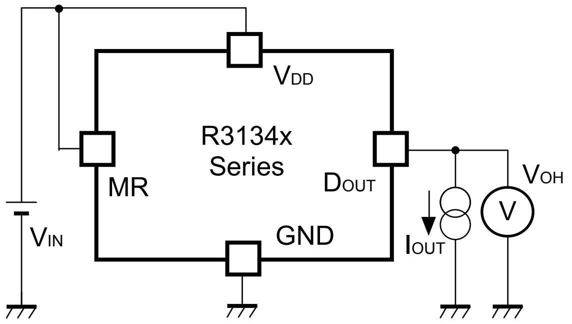


Supply Current Test Circuit



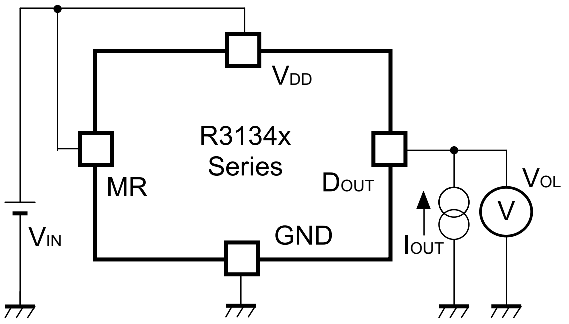
Detector Threshold Test Circuit

(Pull-up circuit is not necessary for CMOS Output type.)

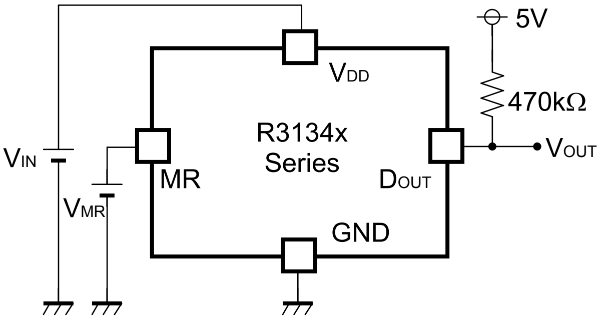


"H" Output Voltage Test Circuit

(CMOS Output Type only)

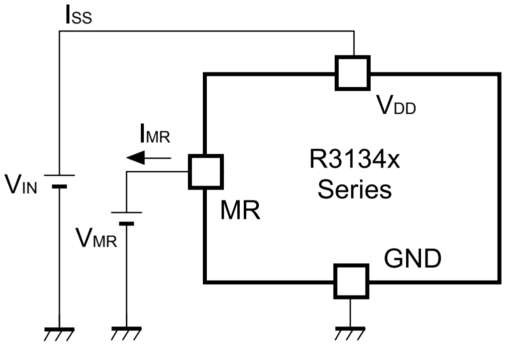


"L" Output Voltage Test Circuit

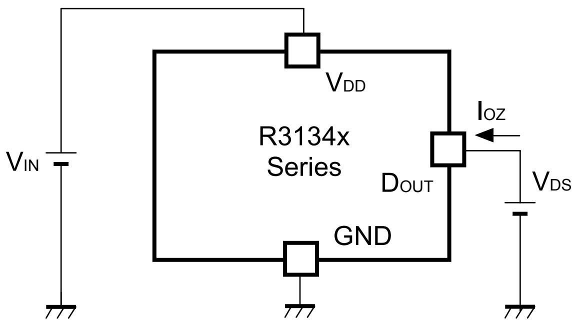


MR pin Input Voltage Test Circuit

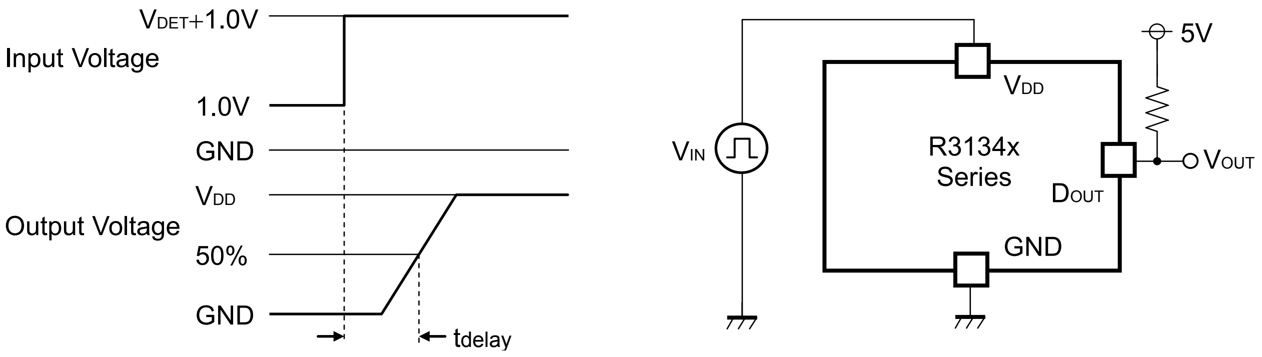
(Pull-up circuit is not necessary for CMOS Output type.)



MR pin Pull-up Resistance Test Circuit



Off Leakage Current Test Circuit



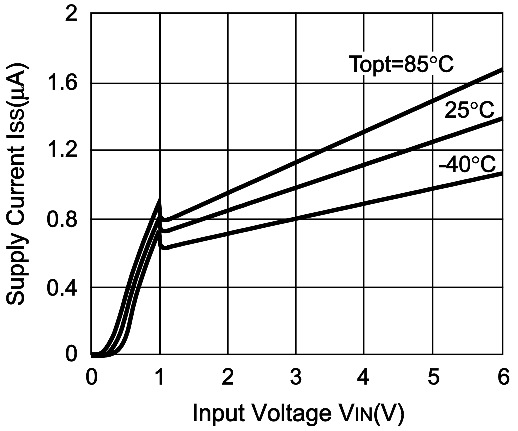
Output Delay Time Test Circuit

(Pull-up circuit is not necessary for CMOS Output type.)

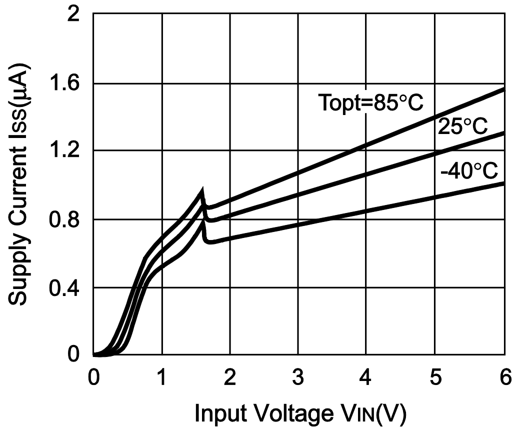
TYPICAL CHARACTERISTICS

1) Supply Current vs. Input Voltage

R3134x10Ex



R3134x16Ex



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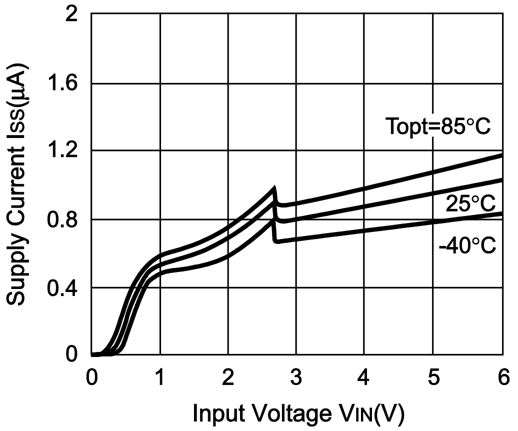
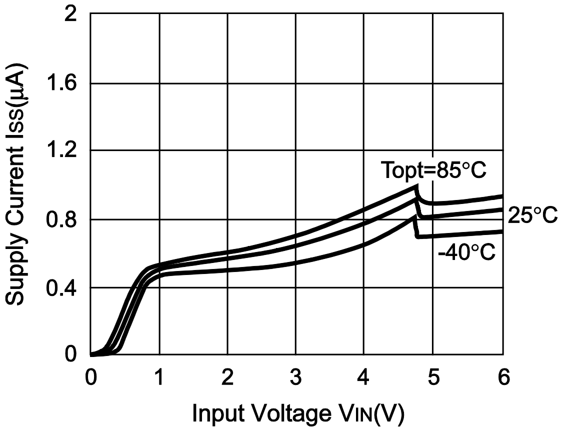
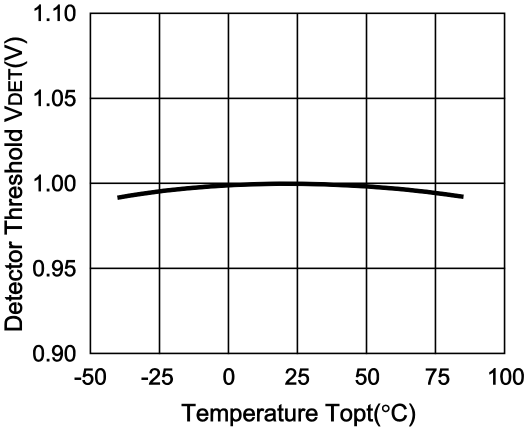


R3134x48Ex



2) Detector Threshold vs. Temperature

R3134x10Ex



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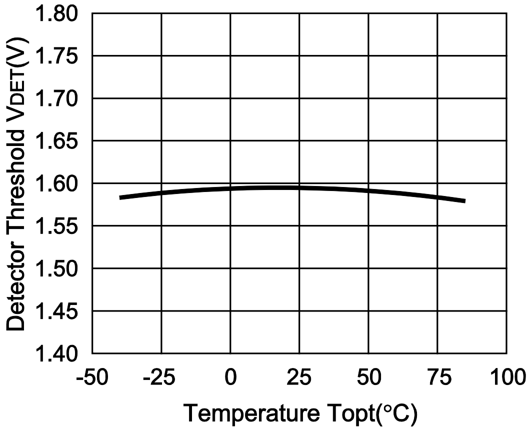

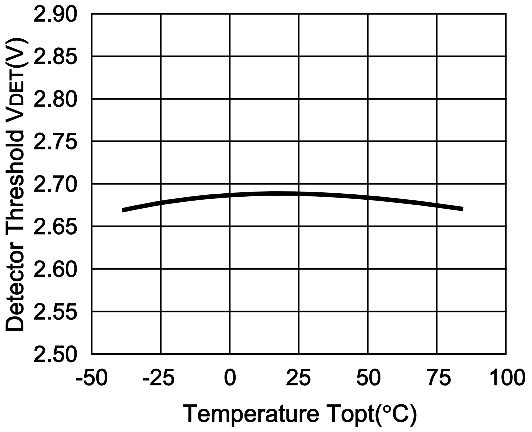

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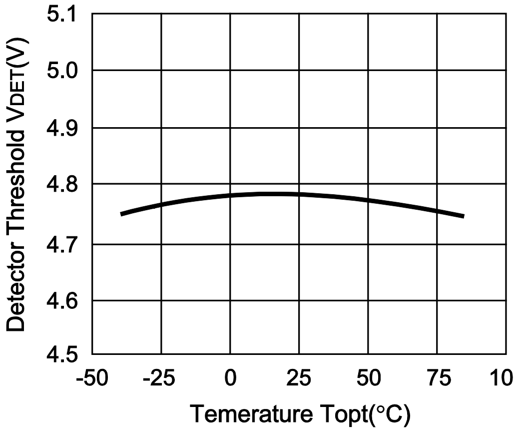
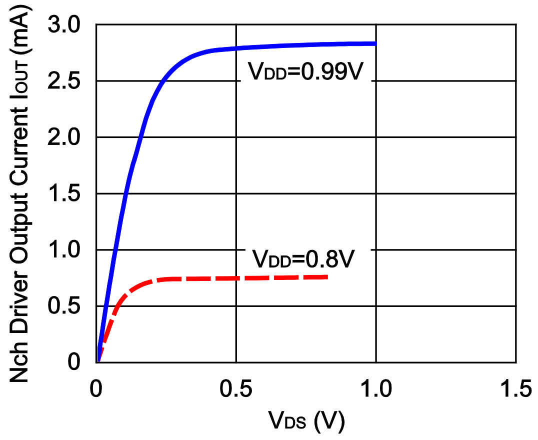
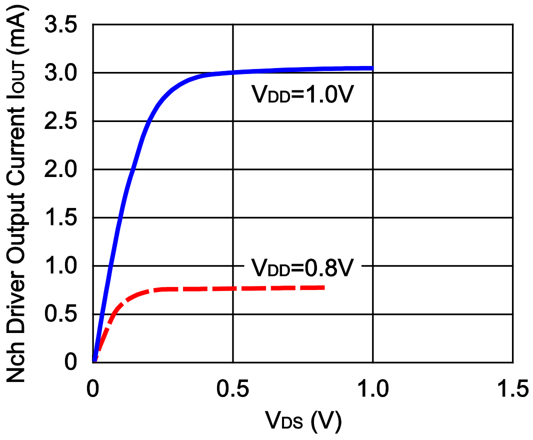


R3134x48Ex

3) Nch Driver Output Current vs. V_{DS} (T_{opt}=25°C)



R3134x10Ex



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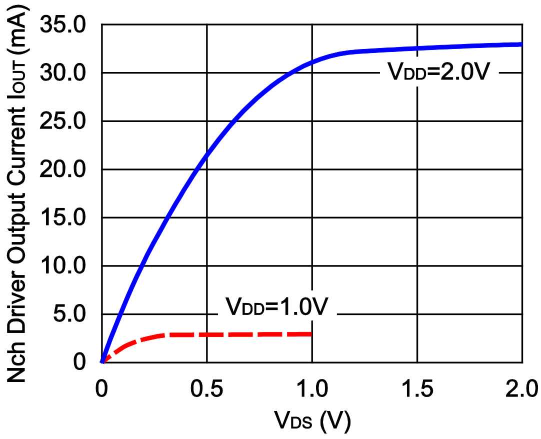
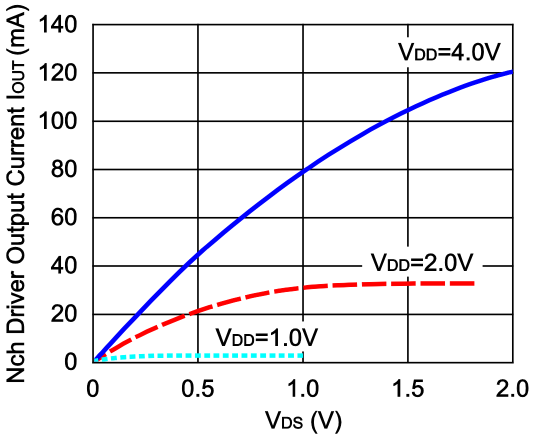


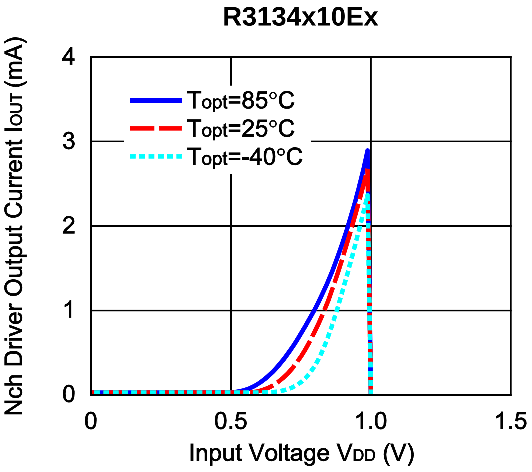
R3134x27Ex

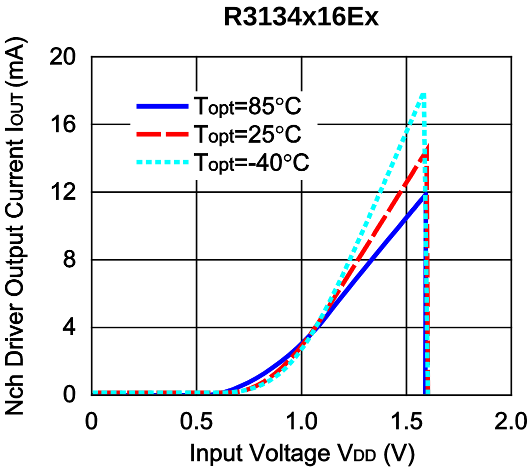


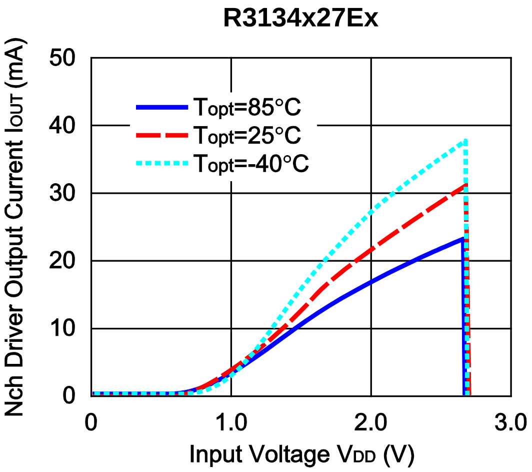
R3134x48Ex

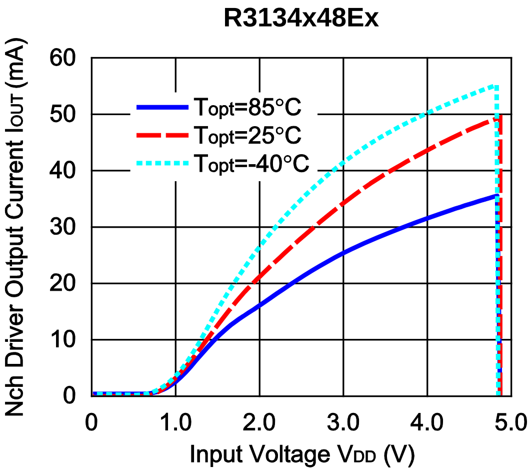
∗ R3134K (DFN(PLP)1212-6) and R3134Q (SC-88A) are the discontinued products as of March, 2016.

4) Nch Driver Output Current vs. Input Voltage

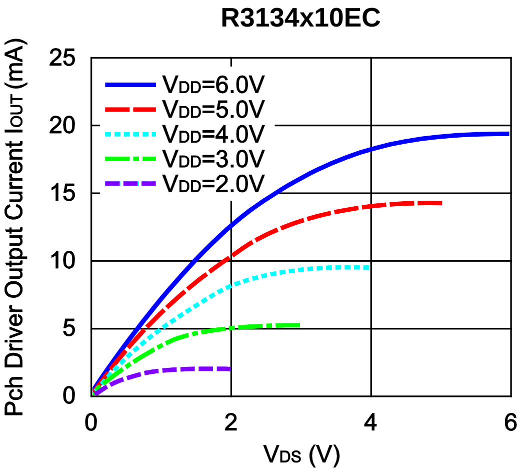


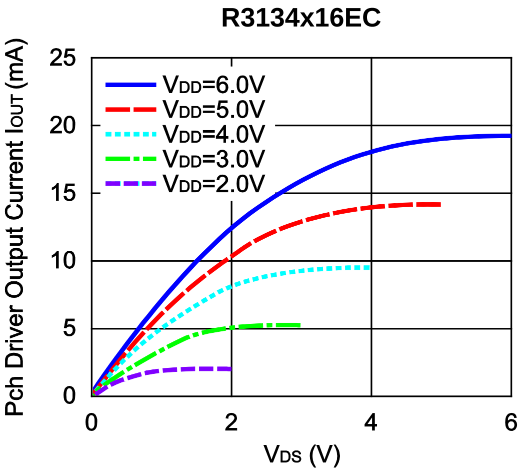


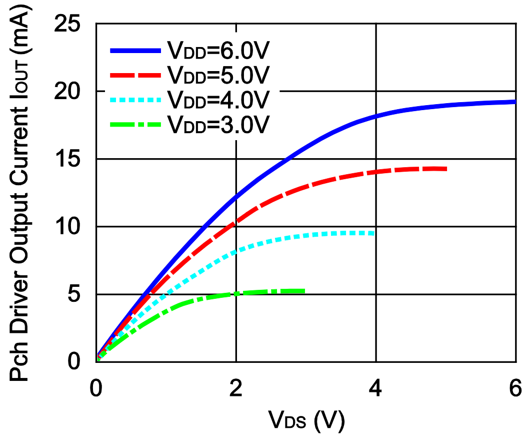


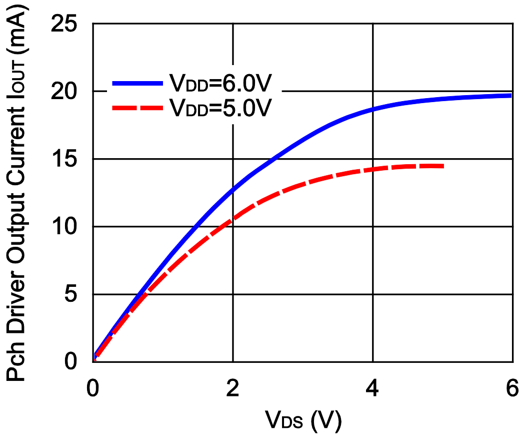


5) Pch Driver Output Current vs. V_{DS}

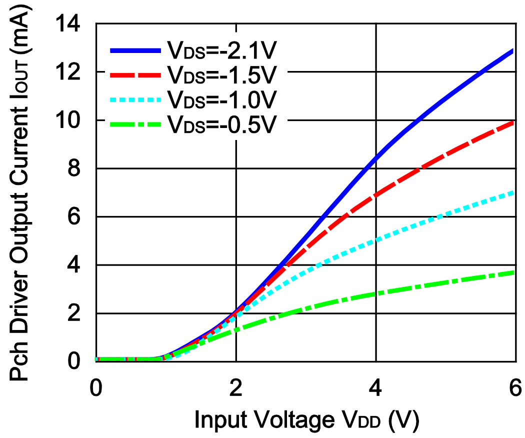


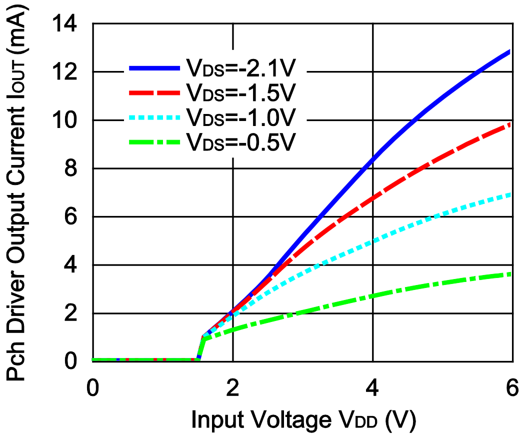



R3134x27EC


R3134x48EC

6) Pch Driver Output Current vs. Input Voltage


R3134x10EC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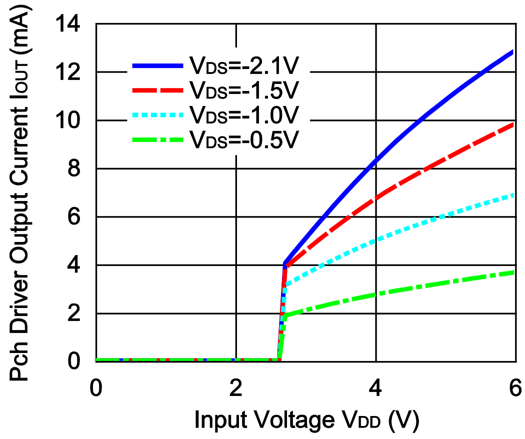
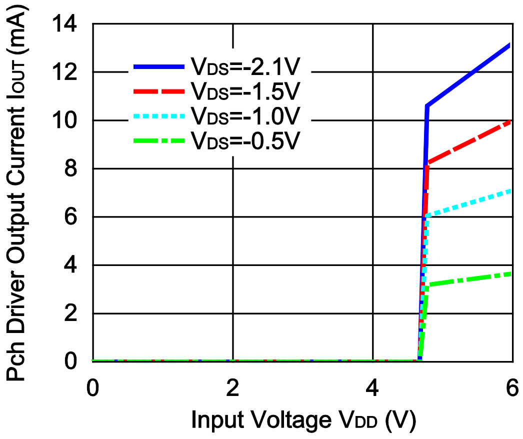
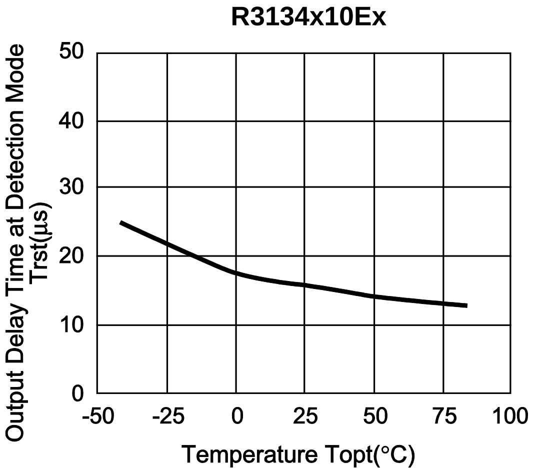
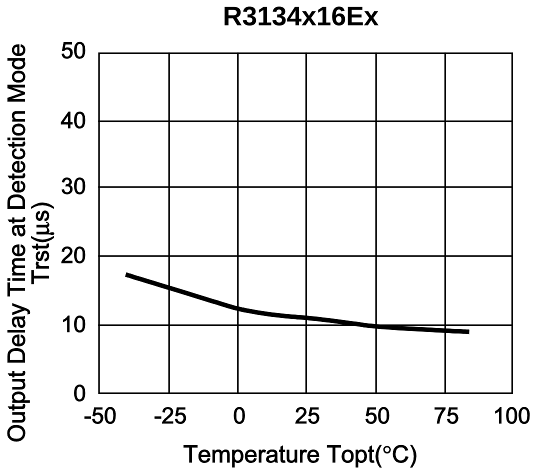
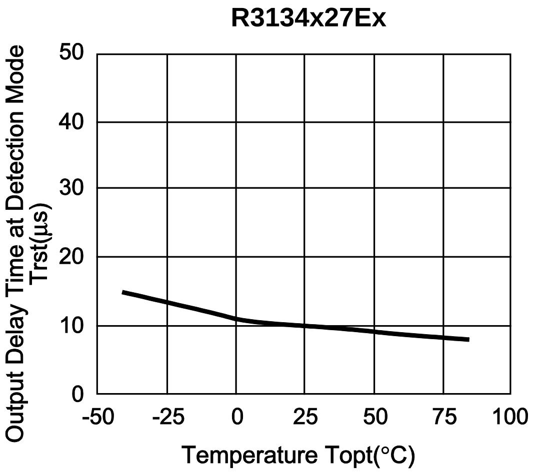

R3134x27EC

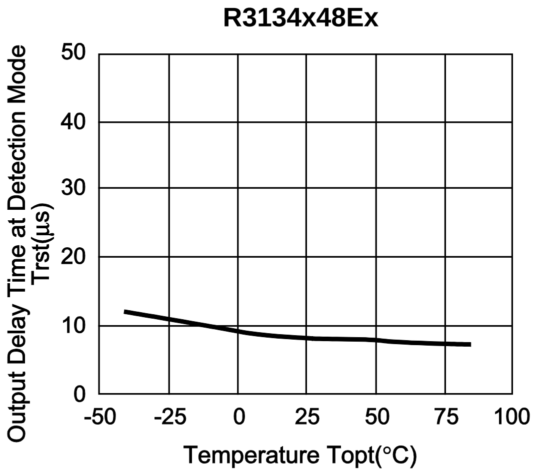

R3134x48EC

7) Output Delay Time at Detection Mode vs. Temperature

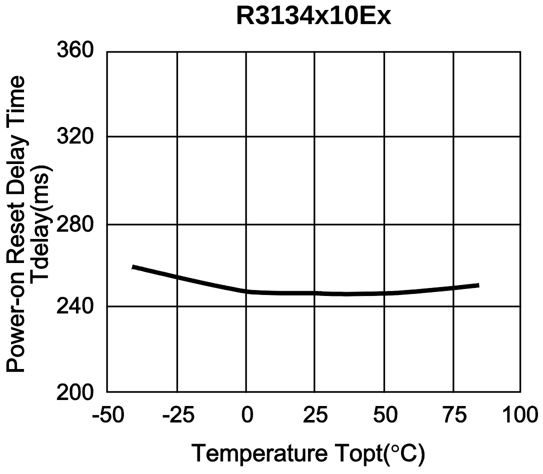


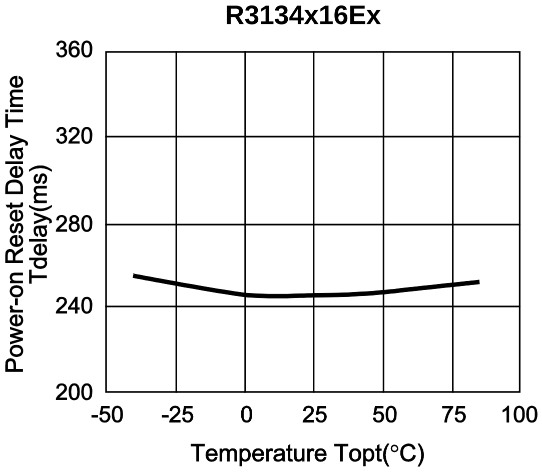


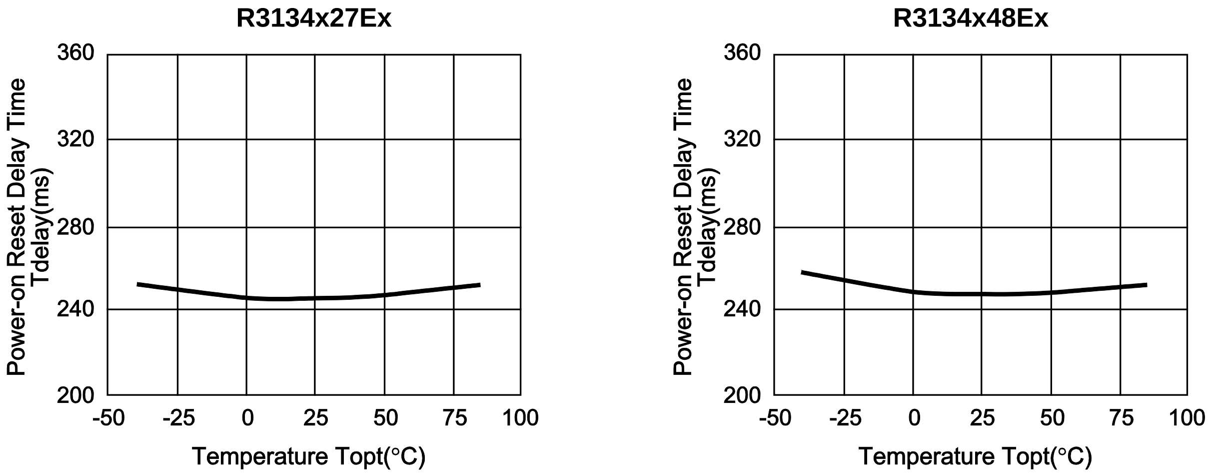




8) Power-on Reset Delay Time vs. Temperature







TECHNICAL NOTES

When connecting resistors to the device's input pin

When connecting a resistor (R1) to an input of this device, the input voltage decreases by [Device's Consumption Current] x [Resistance Value] only. And, the cross conduction current*[1], which occurs when changing from the detecting state to the release state, is decreased the input voltage by [Cross Conduction Current] x [Resistance Value] only. And then, this device will enter the re-detecting state if the input voltage reduction is larger than the difference between the detector voltage and the released voltage.

When the input resistance value is large and the VDD is gone up at mildly in the vicinity of the released voltage, repeating the above operation may result in the occurrence of output.

As shown in Figure A/B, set R1 to become 100 kΩ or less as a guide, and connect C_{IN} of 0.1 μF and more to between the input pin and GND. Besides, make evaluations including temperature properties under the actual usage condition, with using the evaluation board like this way. As a result, make sure that the cross conduction current has no problem.

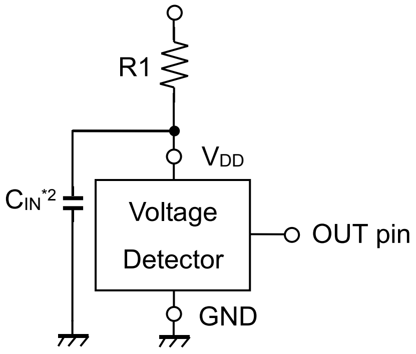


Figure A

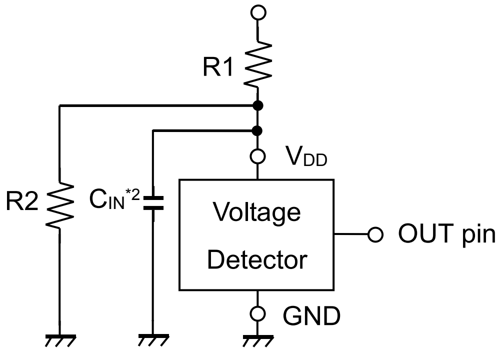


Figure B

*[1] In the CMOS output type, a charging current for OUT pin is included.
*[2] Note the bias dependence of capacitors.

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